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Incidence of mastitis in beef cows after intramuscular administration of oxytetracycline[1]

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ABSTRACT: There is limited information on the value of antibiotic therapy for mastitis in beef cows. Effects of antibiotic treatment at weaning and the subsequent calving on calf weaning weight, milk somatic cell counts, milk components, and intramammary infection were studied in beef cows. Additionally, effects of number of infected mammary quarters, number of dry mammary quarters, type of intramammary pathogen, and parity on response variables were determined. Cows (n = 192) were randomly assigned to treatments in a 2 × 2 factorial arrangement; factors were time of treatment (weaning and after calving) and treatment (vehicle and vehicle plus antibiotic). Oxytetracycline (LA-200) or vehicle was administered intramuscularly following collection of quarter milk samples at weaning and calving. Percentage of infected cows and quarters averaged 43.4 and 16.4%, respectively, at calving and increased ($P < 0.05$) to 53.7 and 29.7% at weaning. Calves from cows with one or two dry quarters weighed 12.7 kg less ($P < 0.05$) at 90 d after calving and 18.7% less ($P < 0.05$) at 212 d after calving than calves from cows with no dry quarters. Calves from cows with three or four infected quarters weighed 17.5 kg less ($P < 0.05$) at 90 d and 25.5 kg less ($P < 0.05$) at weaning than calves from cows with two or fewer infected quarters. Infections by *Staphylococcus aureus* and coagulase-negative staphylococci were the most common and accounted for 67 and 78% of the infections. Percentages of infected cows and quarters, infections caused by *S. aureus*, and dry quarters increased ($P < 0.05$) with parity. No differences were found among antibiotic treatments for any of the response variables studied. Intramuscular oxytetracycline was not effective in the control of mastitis in beef cows under the conditions of the study.

Key Words: Antibiotics, Beef Cows, Mastitis, Milk, Somatic Cell Count, Weaning Weight

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Introduction

Treatment at drying-off is a widely accepted practice for mastitis control in dairy cows (Philpot and Nickerson, 1991; Erskine et al., 1994). In contrast, antibiotic therapy in beef cattle is not an accepted practice and is only used for treatment of clinical cases (Kirkbride, 1977). Mastitis occurs in beef cows with an incidence between 10 and 54% of the cows in a given herd (Newman et al., 1991; Simpson et al., 1995). Reductions in milk production and changes in milk quality due to mastitis have been associated with reduced calf weight gains (Kirkbride, 1977; Watts et al., 1986; Simpson et al., 1995).

Several antibiotics have been widely studied for the treatment of intramammary infections in dairy cows (Eberhart and Buckalew, 1972; Watts et al., 1986). A common practice adopted in dairy cows is to treat cows by intramammary infusions into all four quarters at drying-off (Philpot and Nickerson, 1991). A combination of intramammary infusion together with intramuscular injection of antibiotics may be more effective (Soback et al., 1990; Nickerson et al., 1993). Tetracyclines are broad-spectrum antibiotics that are effective to treat mastitis because of their diverse therapeutic efficacy (Soback et al., 1990; Erskine et al., 1994). They are lipophilic, have a long half-life, and their spectrum of action includes *Staphylococcus aureus* (Erskine et al., 1994). The objectives of this study were to determine the effects of intramuscular administration of oxytetracycline to beef cows at weaning and calving on calf

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weight, milk somatic cell count (**MSCC**), milk composition, and percentages of infected cows and quarters.

Materials and Methods

Animals and Treatment

Hereford and Hereford × Angus cows at the Oklahoma Agricultural Experimental Station in Stillwater were used in a 2 × 2 factorial experiment starting at weaning, through calving, and until the subsequent weaning. Treatments consisted of intramuscular administration of vehicle at weaning, antibiotic at weaning, vehicle at calving, and antibiotic at calving.

At weaning in October, 192 cows were randomly assigned to receive either vehicle or anitibiotics. At calving between February and April, half of the cows on each weaning treatment were randomly assigned to receive either vehicle or antibiotics. Twenty-eight cows had health problems (dystocia, placental retention, still birth, and conjunctivitis) between the weaning periods that merited antibiotic treatment and were removed from the experiment. Cows were maintained on native range and bermudagrass pastures. When pastures were dormant, 20 to 40% CP supplements were fed to maintain cow body condition score between 4 and 5.5 (Wagner et al., 1988).

Vehicle consisted of 40% 2-pyrrolidone (BASF, Parisppany, NJ) and 5% polyvinylpyrrolidone (Aldrich Chemical, Milwaukee, WI) in aqueous sterile solution with pH adjusted to 9.6. Vehicle was injected intramuscularly at a dose of 0.1 mL/kg of birth weight. Antibiotic was an oxytetracycline preparation (Liquamycin LA-200; Pfizer Agricultural Division, New York) injected at a dose of 19.8 mg of oxytetracycline/kg of birth weight. Each milliliter of aqueous sterile antibiotic preparation contained 200 mg of oxytetracycline base, as amphoteric oxytetracycline, and, on a wt/vol basis, 40% 2-pyrrolidone, 5% povidone, 1.8% magnesium oxide, 0.2% sodium, formaldehyde sulfoxylate (as preservative), monoethanolamine, and HCl to adjust pH to 9.6. Intramuscular administration of vehicle and antibiotic was done while animals were restrained in a squeeze chute. Administration was on the lateral upper third of the neck, with only 10 mL per injection site and three sites per side of the neck.

Samples and Analysis

Milk samples were collected for diagnostic bacteriology, MSCC, and analyses of milk composition after calving, between 8 and 14 d postpartum, and at weaning (212 ± 2 d of lactation). Cows were separated from their dams 2 to 3 h prior to milk collection to ensure collection of adequate volumes of milk. Cows were directed into conventional squeeze chutes. Oxytocin (Vedco, St. Joseph, MO) was administered (i.m.) at a dose of 10 units/cow to facilitate milk let-down. Teats were dipped into 0.1% iodine teat dip (Alfa Laval, Agri Inc., Kansas City, MO), wiped dry with paper towels, and scrubbed with 70% ethyl alcohol. The first streams were discarded and 10 mL of milk was collected into snap-cap sterile plastic tubes containing broad-spectrum microtabs as a preservative (D&F Control Systems, San Ramon, CA) for MSCC and analysis of milk composition. Teat ends were again scrubbed with 70% ethyl alcohol and 3 mL of milk was collected aseptically from each teat into snap-cap sterile plastic tubes (Fisher brand, Pittsburgh, PA) for bacteriological analysis.

Milk samples for bacteriological analysis were frozen, packed on Dry Ice, and transported to the Immunology and Disease Resistance Laboratory USDA-ARS, Beltsville, MD for diagnostic bacteriology. Milk samples collected for MSCC and milk composition were analyzed at the DHI laboratory at Oklahoma State University in Stillwater.

For diagnostic bacteriology, frozen milk samples were allowed to thaw at room temperature and vortexed before plating. Twenty microliters of milk was plated on one-fourth of an esculin blood agar plate (5% red blood cells), mannitol plates, and on P-agar plates supplemented with acriflavine. Plates were incubated at 37°C and examined for bacterial growth at 24 and 48 h. Criteria applied for considering infection, contamination, and for identification of microorganisms were those established by the National Mastitis Council (NMC, 1987).

Milk SCC were determined electronically by a fluoro-opto-electronic method (Bently Instrument Somacount 300, Bentley Instrumental, Chasca, MN), using reference standards (DQCI Services, Mounds View, MN) for calibration. Milk components were determined by near infrared spectroscopy (Multi-Spec; Multispect Inc., Wheldrake, York, U.K.). Calf weights were recorded at birth between February and April, at an intermediate period during June, and at weaning in October using a livestock scale.

Statistical Analysis

Effect of antibiotic administration was studied in two data sets. First, the effect of treatment at weaning (vehicle or antibiotics) was analyzed for the postcalving period (n = 164 cows). Second, the effects of treatment at weaning (vehicle or antibiotics), treatment at calving (vehicle or antibiotics), and their interaction were analyzed at the subsequent weaning. Weaning data for 49 cows were not used in the second data set (n = 115 cows) because calves from these randomly selected cows were weaned early for a companion experiment.

Additionally, the effect of number of infected quarters (zero to four) alone or in association with pathogen group (zero, one or two major, one or two minor, three or four major, or three or four minor), number of dry quarters (zero, one, or two), type of bacterial isolate (uninfected, coagulase-negative staphylococci [**CNS**], *S. aureus*, and "other" [*Bacillus* spp., *Corynebacterium bovis*, *Streptococcus* spp. not *Strep. agalactiae*, and un-

determined isolates]), and parity of the cows (2, 3 to 5, or 6 to 10) on response variables were also studied. Within pathogen group, major pathogens consisted of *S. aureus* isolates and minor pathogens consisted of *Bacillus* spp., CNS, *Corynebacterium bovis*, *Streptococcus* spp. not *Strep. agalactiae*, and undetermined isolates. The CNS included *Staphylococcus hyicus*, *Staphylococcus chromogenes*, *Staphylococcus epidermidis*, *Staphylococcus cohnii*, *Staphylococcus warneri*, and *Staphylococcus hominis* after calving and *S. hyicus*, *S. chromogenes*, and *S. epidermidis* at weaning. Calf weight was analyzed at weaning in October and at an intermediate date between birth and weaning in June.

Actual counts for MSCC were transformed to natural logarithm for analysis. Tests for outliers for milk composition were conducted and data falling between the following ranges were used for statistical analysis: 2.8 to 5.0% for protein, 1.2 to 6.5% for butterfat, 3.0 to 5.5% for lactose, and 7.9 to 11.0% for solids-not-fat (**SNF**). Cows and calf breeds were not included in the models because of the lack of a breed effect for Angus and Angus × Hereford cows in previous experiments.

Response variables were calf birth weight, calf weaning weight, MSCC, milk composition (protein, butterfat, lactose, and SNF), percentage of infected cows, percentage of infected quarters, percentage of infected quarters by CNS, percentage of infected quarters by *S. aureus*, percentage of infected quarters by "other" isolates, and percentage of blind quarters. Milk and mammary variables were evaluated after calving and at weaning.

Different statistical models were used for analysis of postcalving data and weaning data. In all cases, preliminary models were developed based on the independent variables and meaningful first-order interactions. Preliminary analyses of variance indicated that most high-order interactions were not significant or did not allow for the correct estimation of the degrees of freedom for any of the variables studied; therefore, these interactions were deleted from the models.

Calf birth weight, calf weights in June, calf weights at weaning, and percentage of infected cows were analyzed using GLM procedures of SAS (SAS Inst. Inc., Cary, NC). The rest of the variables were analyzed using the MIXED procedure of SAS, in which cow nested within parity, calf sex, and treatment at weaning for the postcalving data and cow nested within parity, calf sex, treatment at weaning, and treatment at calving for the weaning data analysis were the random variables.

The effect of parity on the percentage of cows and quarters infected and percentage of quarters infected with CNS, *S. aureus*, and other bacteria was analyzed by chi-square (Ostle, 1964). Effect of parity on percentage of blind quarters was not analyzed because some expected values were too small and the chi-square statistic may not be a valid test.

Least squares means and probability for contrasts of interest were estimated for calf birth weight, calf weight in June, calf weaning weight, MSCC, milk composition and the different percentages studied except for those reported according to cow parity. Unbalanced distribution of cows for the latter did not allow for the correct estimation of least squares means. Consequently, means for percentages studied according to cow parity were calculated using the MEANS procedure of SAS.

Results and Discussion

Calf Weight

Neither calf weaning weight nor intermediate calf weight was affected ($P > 0.10$) by the combination of antibiotic treatment at weaning and treatment after calving (data not shown). Intermediate (90 ± 2 d) and weaning (212 ± 2 d) weights averaged 128 and 214 kg, respectively. To our knowledge, only one unpublished study examined effects of antibiotic use in beef cows on calf weight (D. Burnside as quoted by Kirkbride, 1977). In that study, cows were divided into two groups: one group received antibiotic treatment in all quarters and the other group was the untreated control. Calves nursing treated cows were 12.5% heavier than calves nursing untreated cows at 60 d of age (Kirkbride, 1977). Several reasons could be listed to explain why calf weights were not different among treatments in the current experiment. These include no therapeutic effect of antibiotic treatment, small differences in milk production between infected and uninfected cows that would not compromise the required nutrient supply to the calf, confounding effect of other nutrient supplies such as pasture, or a combination of the above. There might be differences among breeds of calves in relation to the time in which calves switch from nursing to pasture. Therefore, calf weight in the present experiment would not only reflect the dam's milk production, but also additional sources of nutrients from pastures.

Most studies testing the efficacy of intramammary infusion, and to a lesser degree the efficacy of intramuscular administration of antibiotics for the treatment of mastitis, have been conducted in dairy cows (Natzke et al., 1966; Philpot, 1969; Eberhart and Buckalew, 1972). Studies have demonstrated that dry-off therapy should be preferred to lactational therapy (Philpot, 1969; Pankey et al., 1982). Several drying-off products for intramammary infusion have been developed for this purpose (Watts et al., 1995). Dry-off therapy has been successful in eliminating existing infections and in preventing new infections during the nonlactating period (Eberhart and Buckalew, 1972; Eberhart, 1986; Soback et al., 1990). In the present experiment, antibiotic treatment was applied to beef cows at weaning, which is equivalent to drying-off in dairy cows, and after calving.

We hypothesized that treatment of beef cows with antibiotics would reduce subclinical mastitis and milk production would increase. Cows with mastitis usually have less milk production than uninfected cows (Watts et al., 1986; Houben et al., 1993), and calf weaning weights are a reflection of the dam's milk production

Table 1. Effect of number of infected quarters of the dam at calving on calf weight and milk somatic cell counts (MSCC)

Item	Number of infected quarters[a]						Contrast ($P <$)[b]		
	0	1	2	3	4	SE[c]	0 vs 1 to 2	0 vs 3 to 4	1 to 2 vs 3 to 4
Calf weight, kg									
Birth	38.6	37.6	37.3	36.5	32.1	1.8	NS[d]	0.10	NS
Intermediate[e]	134	129	132	123	118	4.3	NS	0.01	0.05
Weaning[f]	225	215	216	208	203	7.1	0.10	0.10	NS
Postcalving[g] MSCC, cells × 10^3/mL[h]	27.0	70.3	94.1	103.7	547.7	1.6	0.001	0.01	NS
Weaning MSCC, cells × 10^3/mL[h]	19.2	29.6	70.5	203.6	121.2	1.4	0.001	0.001	0.01

[a]Number of infected quarters; n = 48, 18, 25, 12, and 6 for zero, one, two, three, and four infected quarters, respectively.
[b]Overall ANOVA was significant for calf weight and MSCC.
[c]SE = pooled standard error.
[d]NS = not significant ($P > 0.10$).
[e]Intermediate weight was measured in mid-June at an average age of 90 ± 2 d.
[f]Weaning occurred in mid-October at an average age of 212 ± 2 d. Range of Julian birth date was 38 to 117 d.
[g]Milk samples were collected 8 to 14 d postpartum.
[h]Analysis was performed on data transformed to natural log.

(Jeffrey et al., 1971). Dairy cows with chronic intramammary infections produced on average 14% less milk during a single lactation (Houben et al., 1993). Amount of milk produced decreases with the severity of the infection (Harmon, 1994). Despite this reduction, calf weights are not necessarily a reliable indicator of a dam's milk production, because the differences in milk production between infected and uninfected cows becomes significant only after the 2nd or 3rd mo of lactation (Houben et al., 1993) and corresponds to the time when calves start consuming forage. Additionally, milk production losses may go undetected in beef cows because the risk of contracting mastitis is greater in high-producing cows (Houben et al., 1993).

Birth and intermediate weights of calves for cows with no infected quarters were not different ($P > 0.10$) from those of calves nursing cows with one or two infected quarters (Table 1). Weaning weights tended to be greater ($P < 0.10$) for calves that nursed cows with no infected quarters than for calves nursing cows with one or two infected quarters. Birth weights and weaning weights tended to be greater ($P < 0.10$) and intermediate weight was greater ($P < 0.01$) for calves nursing cows with no infected quarters than for calves nursing cows with three or four infected quarters. When comparing weights of calves nursing cows with one or two infected quarters to those of calves nursing cows with three or four infected quarters, birth and weaning weight were not different ($P > 0.10$) and intermediate calf weights were greater ($P < 0.05$) for calves nursing cows with one or two infected quarters. Differences in weaning weight in the present study were less than the differences found by Watts et al. (1986). However, in both studies birth, intermediate, and weaning weights decreased consistently as the number of infected quarters increased.

Infection with major or minor pathogens at calving had similar effects on intermediate and weaning weight (Table 2). Intermediate and weaning weight were greater ($P < 0.001$ and $P < 0.01$, respectively) for calves nursing cows with no infected quarters than those for calves nursing cows with one to four quarters infected with major pathogens and greater ($P < 0.05$) than for calves nursing cows with one to four quarters infected with minor pathogens. In addition, both intermediate and weaning weight were less ($P < 0.01$ and $P < 0.05$, respectively) for calves nursing cows with one or two quarters infected with major pathogens than for calves nursing cows with one or two quarters infected with minor pathogens. On the contrary, no difference ($P > 0.10$) in intermediate and weaning weight was observed among calves nursing cows with three or four quarters infected with major pathogens and for calves nursing cows with three or four quarters infected with minor pathogens. These results are in agreement with other studies in which calves nursing cows infected with *S. aureus* had lesser weaning weight at 205 and 210 d than calves nursing uninfected cows (Haggard et al., 1983; Watts et al., 1986; Newman et al., 1991). Results indirectly support the observation that the reduction in milk production due to mastitis depends on the pathogens involved (Lucey et al., 1986). Others have found no difference in 205-d weaning weight among calves nursing cows infected or uninfected with *S. aureus* (Simpson et al., 1995). Newman et al. (1991) found that infection of cows with *S. aureus* did not alter the weight of calves at 100 d. Similarly, no differences were found in weaning weight of calves nursing *C. bovis*-infected cows compared with weaning weights of calves nursing uninfected cows (Newman et al., 1991). Newman et al. (1991) also demonstrated that during the periods of 0 to 100 d and 0 to 205 d weights of calves nursing cows infected with any pathogen did not differ from those of calves nursing uninfected cows. This finding is not in agreement with the current study.

Calf weights were also analyzed according to the number of dry or blind quarters (Table 3). Intermediate and weaning weights were approximately 17 and 25 kg greater ($P < 0.05$) for calves nursing cows with no blind quarters than for calves nursing cows with one or two

Table 2. Effect of number of infected quarters of the dam at calving and type of pathogen on calf weight

Item	Number of infected quarters and pathogen group[a]						Contrast ($P <$)[b,c]			
	0	1 or 2 major	1 or 2 minor	3 or 4 major	3 or 4 minor	SE[d]	A	B	C	D
Number of cows	53	15	29	14	5					
Calf weight, kg										
Intermediate[e]	135	121	135	123	117	4.2	0.001	0.05	0.01	NS[f]
Weaning[g]	226	203	221	211	196	7.2	0.01	0.05	0.05	NS

[a]Pathogen group consisted of major and minor pathogens. When both major and minor pathogens were found in the same cow, it was assigned to the major pathogen group regardless of the number of infected quarters with either one of them. Major pathogens included *Staphylococcus aureus*. Minor pathogens included *Bacillus* spp., coagulase-negative Staphylococci (*S. hycius*, *S. chromogenes*, *S. epidemidis*), *Corynebacterium bovis*, *Strepococcus* spp. not *Strep. agalactiae*, and undetermined isolates.
[b]Overall ANOVA was significant.
[c]Contrasts: A = 0 vs major, B = 0 vs minor, C = 1 to 2 major vs 1 to 2 minor, D = 3 to 4 major vs 3 to 4 minor.
[d]SE = pooled standard error.
[e]Intermediate weight was measured in mid-June at an average age of 90 ± 2 d.
[f]NS = not significant ($P > 0.10$).
[g]Weaning occurred in mid-October at an average age of 212 ± 2 d. Range of Julian birth date was 38 to 117 d.

blind quarters. Intermediate and weaning weight were not different ($P > 0.10$) between calves nursing cows with one or two blind quarters. These results suggest that cows with blind quarters produced less milk than cows with no blind quarters and that cows with one or two blind quarters produced similar amounts of milk.

Calves from cows of 2 parities had lighter ($P < 0.001$) birth weights but greater ($P < 0.05$) weaning weight than calves from cows with 3 to 10 parities (Table 4). No difference ($P > 0.10$) in birth and weaning weight were observed for calves from cows with 3 to 5 and 6 to 10 parities. Intermediate weights were greater ($P < 0.05$) for calves from cows with 6 to 10 parities than for calves from cows with 3 to 5 parities. In the present study, calves nursing cows of two parities had greater weaning weight than calves nursing older cows, which is in disagreement with Watts et al. (1986). Beef cows approach maturity at 4 to 5 yr of age (Day et al., 1987) and achieve peak milk production at 6 yr of age (Marlowe and Gaines, 1958; Sellers et al., 1970). If calf weaning weight were entirely related to milk production, heavier calves from older cows would be expected. Other factors such as cross-suckling (Newman et al., 1991), forage availability (Neville, 1962; Day et al., 1987), breed, genetic differences, and mammary health may have influenced calf weaning weight. For example, the number of lactations ranging from 1 to 5 in first-generation (F_1) beef-dairy cows did not influence calf 205-d weaning weight (Wilson et al., 1971).

Milk Somatic Cell Count

Antibiotics administered to cows at weaning (vehicle or antibiotics) had no effect ($P > 0.10$) on MSCC after calving (data not shown) and averaged 88×10^3 cells/mL for both treatments. Similarly, any of the combinations of antibiotic treatments administered to cows at weaning and after calving had no effect ($P > 0.10$) on MSCC at the subsequent weaning (data not shown) and averaged 97×10^3 cells/mL across treatments. There is sufficient evidence to indicate that increased MSCC is indicative of intramammary infection (Berning and Shook, 1992; Deluyker et al., 1993; Harmon, 1994) and that treatment with antibiotics is useful to reduce infections (Eberhart and Buckalew, 1972; Eberhart, 1986; Nickerson et al., 1993). We failed to find differences in MSCC between untreated and antibiotic-treated cows. Results imply that antibiotic treatment was ineffective in reducing intramammary infections. Although no differences in MSCC were detected among treatments, MSCC in all treatments were below 108×10^3 cells/mL, typical of uninfected quarters in dairy cows; SCC above 200×10^3/mL are indicative of infected quarters in dairy cows (Paape and Contreras, 1997). Thus, there is the

Table 3. Effect of nonlactating or blind quarters at calving on calf weight

Calf weight	Number of blind quarters[a]				Contrast ($P <$)[b]	
	0	1	2	SE[c]	0 vs 1 to 2	1 vs 2
Intermediate, kg[d]	132	114	116	5.0	0.05	NS[f]
Weaning, kg[e]	215	189	190	8.4	0.05	NS

[a]n = 97, 8, and 3 cows for 0, 1, and 2 blind quarters, respectively.
[b]Overall ANOVA was significant.
[c]SE = pooled standard error.
[d]Intermediate weight in mid-June at an average age of 90 ± 2 d.
[e]Weaning in mid-October at an average age of 212 ± 2 d.
[f]NS = not significant ($P > 0.10$).

Table 4. Effect of parity of the dam on calf weight and quarter milk somatic cell counts (MSCC) and composition

Item	Parity[a]				Contrast ($P <$)[b]	
	2	3 to 5	6 to 10	SE[c]	2 vs 3 to 10	3 to 5 vs 6 to 10
Calf weight, kg						
Birth	34.1	38.2	39.1	0.92	0.001	NS[h]
Intermediate[d]	127.7	122.0	128.8	9.73	NS	0.05
Weaning[e]	225.8	202.7	205.6	6.05	0.05	NS
Postcalving[f] MSCC, cells $\times 10^3$/mL[g]	64.2	72.7	146.7	1.21	0.10	0.10
Weaning MSCC, cells $\times 10^3$/mL[g]	76.6	96.6	123.0	1.27	NS	NS
Milk components, %						
Postcalving[e]						
Protein	3.53	3.51	3.48	0.05	NS	NS
Butterfat	2.74	3.21	3.54	0.17	0.05	0.10
Lactose	4.87	4.83	4.82	0.04	NS	NS
SNF	9.16	9.10	9.02	0.06	NS	NS
Weaning[e]						
Protein	3.35	3.55	3.55	0.07	NS	NS
Butterfat	2.78	3.67	4.07	0.26	0.05	0.10
Lactose	4.82	4.76	4.66	0.05	NS	0.05
SNF	8.89	9.05	8.96	0.09	NS	NS

[a]N = 7, 36, and 67 cows for parity 2, 3 to 5, and 6 to 10, respectively.
[b]Overall ANOVA was significant for calf weight, butterfat, and lactose.
[c]SE = polled standard error.
[d]Intermediate weight in mid-June at an average age of 90 ± 2 d.
[e]Weaning in mid-October at an average age of 212 ± 2 d.
[f]Milk samples were collected 7 to 14 d postpartum.
[g]Analysis was performed on data transformed to natural log.
[h]NS = not significant ($P > 0.10$).

possibility that antibiotic treatment could be effective in reducing MSCC in beef cows with MSCC above 200 $\times 10^3$ cells/mL.

Milk SCC increased as the number of infected quarters increased from zero to four after calving and at weaning (Table 1). After calving and at weaning, cows with no infected quarters had lower MSCC than cows with one or two infected quarters and cows with three or four infected quarters ($P < 0.001$ and $P < 0.01$, respectively). After calving, MSCC of cows with one or two infected quarters were not different ($P > 0.10$) from those of cows with three or four infected quarters. However, at weaning, MSCC was lower ($P < 0.01$) for cows with one or two infected quarters than for cows with three or four infected quarters. Milk SCC for uninfected quarters in the present study after calving and at weaning were in agreement with values reported previously during different stages of lactation (Newman et al., 1991). Watts et al. (1986) found greater MSCC for uninfected quarters than those reported in this study. In Angus-Holstein cows, MSCC tended to be greatest in early lactation, declined as lactation progressed, and increased abruptly toward the end of lactation (Wilson et al., 1971). In the present study, MSCC of infected quarters after calving were greater than values at weaning. In agreement with the current study, Watts et al. (1986) found the highest MSCC in early lactation.

Milk SCC tended to increase with parity after calving but not at weaning (Table 4). Cows with 2 parities tended to have lower ($P < 0.10$) MSCC after calving than cows with 3 to 10 parities, and cows with 3 to 5 parities tended to have lower ($P < 0.10$) MSCC than cows with 6 to 10 parities. These results confirm that the risk of infection increases as parity increases (Blackburn, 1966; Houben et al., 1993). Similar to our results at weaning, but contrary to our results after calving, Wilson et al. (1971) found that the number of parities ranging from one to five did not influence MSCC in Angus-Holstein F_1 cows. Milk SCC for cows of one to five parities in the study of Angus-Holstein F_1 were greater than the MSCC in our cows with two to five parities, which might be related to the dairy component of the F_1 cows, which could have influenced the greater MSCC. Milk SCC for cows of 6 to 10 parities in the present study were the greatest of all the parity groups and were similar to MSCC for Angus-Holstein F_1 cows of one and two parities (Wilson et al., 1971).

After calving and at weaning, uninfected quarters consistently had the least MSCC, followed by "other," CNS, and *S. aureus* infected quarters. Milk SCC for uninfected quarters were less than MSCC for infected quarters after calving ($P < 0.001$) and at weaning ($P < 0.001$) (Table 5). In addition, after calving and at weaning MSCC for uninfected quarters were less ($P < 0.001$) than those for quarters infected with *S. aureus*.

Percentages of protein, butterfat, lactose, and SNF in milk after calving were not affected ($P > 0.10$) by administration of antibiotics to the cows at weaning (data not shown) and averaged 3.5, 3.2, 4.8, and 9.1%, respectively, across treatments. Similarly, antibiotics administered to cows at weaning and after calving had no effect ($P > 0.10$) on percentages of milk components

at weaning (data not shown). In dairy cows, differences in milk composition have been related to cows that received a single intramuscular antibiotic administration at drying-off. Percentages of protein and lactose increased when penicillin was administered, and lactose percentage increased when streptomycin was administered (Natzke et al., 1966). Differences between these observations and ours could be attributed to the different type of antibiotic used and could also reflect the lack of effect that antibiotics had on calf weight and MSCC, as described previously, in the current study. Changes in percentage of lactose have been suggested to be indicative of intramammary infections (Berning and Shook, 1992). This relationship would agree with results from experiments with dairy cows (Natzke et al., 1966). In the current study, treatment with antibiotics did not influence lactose in milk. This indicates that lactose percentage is probably affected by the type of bacterial isolate rather than by the presence of mastitis per se, as previously described (Harmon, 1994).

Parity did not affect ($P > 0.10$) the majority of the components of milk after calving or at weaning (Table 4). Percentages of butterfat after calving and at weaning were lower ($P < 0.05$ and $P < 0.05$, respectively) in milk from cows with 2 parities than in milk from cows with 3 to 10 parities. Among cows with 3 to 10 parities, percentages of butterfat in milk tended to be greater ($P < 0.10$) after calving and at weaning in cows with 6 to 10 parities than in cows with 3 to 5 parities. At weaning, percentage of lactose in milk was greater ($P < 0.05$) in cows with 3 to 5 parities than in cows with 6 to 10 parities.

The effect of type of bacterial isolate on percentages of milk components after calving and at weaning are presented in Table 5. After calving, percentages of butterfat ($P < 0.10$), lactose ($P < 0.001$), and SNF ($P < 0.05$) were greater but the percentage of protein was lower ($P < 0.001$) in milk from uninfected quarters than in milk from infected quarters. Percentages of lactose ($P < 0.001$) and SNF ($P < 0.01$) were greater and the percentage of protein was lower ($P < 0.001$) in uninfected quarters than in *S. aureus*-infected quarters. Butterfat was not different ($P > 0.10$) in milk from uninfected and *S. aureus*-infected quarters. Among infected quarters, percentages of lactose ($P < 0.001$) and SNF ($P < 0.05$) were lower and the percentage of protein was greater ($P < 0.001$) in milk from *S. aureus*-infected quarters than in milk from quarters infected with CNS and "other" bacterial isolates. The percentage of butterfat did not differ ($P > 0.10$) between quarters with *S. aureus* and those with CNS or "other" bacteria.

At weaning, percentages of butterfat ($P < 0.01$), lactose ($P < 0.001$), and SNF ($P < 0.001$) were greater for uninfected quarters than for infected quarters. Percentages of lactose and SNF were greater ($P < 0.001$) for uninfected quarters than for *S. aureus*-infected quarters. However, protein percentage tended to be lower ($P < 0.10$) in milk from uninfected quarters than in milk from infected quarters. Percentages of lactose and SNF for *S. aureus*-infected quarters were lower ($P < 0.001$)

Table 5. Effect of bacterial isolates on milk somatic cell counts (MSCC) and milk components

	Type of bacterial isolate					Contrast ($P <$)[a]		
Item	Uninfected[b]	CNS[c]	*S. aureus*[d]	Others[e]	SE[f]	Uninfected vs infected	Uninfected vs *S. aureus*	*S. aureus* vs CNS + others
Postcalving[g] MSCC, cells × 10^3/mL[h]	33.7	104.4	415.9	41.3	1.21	0.001	0.001	0.001
Weaning[f] MSCC, cells × 10^3/mL[h]	22.5	231.3	501.1	33.8	1.22	0.001	0.001	0.001
Milk components, %								
Postcalving[g]								
Protein	3.46	3.48	3.61	3.48	0.04	0.001	0.001	0.001
Butterfat	3.28	3.18	3.24	2.95	0.15	0.10	NS[j]	NS
Lactose	4.96	4.86	4.65	4.90	0.03	0.001	0.001	0.001
SNF	9.13	9.06	9.00	9.18	0.05	0.05	0.01	0.05
Weaning[i]								
Protein	3.47	3.48	3.48	3.50	0.05	0.10	NS	NS
Butterfat	3.63	3.46	3.46	3.47	0.19	0.01	NS	NS
Lactose	4.81	4.71	4.65	4.82	0.04	0.001	0.001	0.001
SNF	9.02	8.92	8.87	9.07	0.06	0.001	0.001	0.001

[a]Overall ANOVA was significant for MSCC and milk components.
[b]Uninfected consisted of no bacterial isolate; n = 311 mammary quarters.
[c]CNS: coagulase-negative Staphylococcus grouped the following species; at postcalving: *Staphylococcus hycius*, *S. chromogenes*, *S. epidermidis*, *S. cohnii*, *S. warnei*, *S. hominis*; at weaning: *S. hycius hycius*, *S. hycius chromogenes*, *S. epidermidis*; n = 36 mammary quarters.
[d]*S. aureus*; n = 47 mammary quarters.
[e]Others consisted of *Bacillus* spp., *Corynebacterium bovis*, *Streptococcus* spp. not *Strep. agalactiae*, and undetermined isolates; n = 43 mammary quarters.
[f]SE = pooled standard error.
[g]Milk samples were collected 7 to 14 d postpartum.
[h]Analysis was performed on data transformed to natural log.
[i]Weaning in mid-October at an average age of 212 ± 2 d.
[j]NS = not significant ($P > 0.10$).

than those for CNS and "other" infected quarters. Percentages of protein and butterfat for uninfected quarters were not different ($P > 0.10$) from those for quarters infected with *S. aureus*, and protein and butterfat were similar for *S. aureus*-infected quarters and quarters infected with CNS and "other" isolates.

Major pathogens usually affect compositional changes in milk, whereas minor pathogens are infrequently associated with marked compositional changes (Harmon, 1994). Mastitis infections are associated with decreased percentages of lactose and fat, attributable to reduced synthetic activity of the infected tissue (Harmon, 1994). Total proteins undergo little change, although the types of proteins change dramatically; the major protein, casein, decreases and whey proteins increase. In the current study, differences in lactose percentage among quarters infected with different bacterial groups are in agreement with the previous observation that reduction in lactose percentage could be used to predict mastitis (Berning and Shook, 1992). Moreover, in agreement with a previous report (Harmon, 1994) the most pathogenic bacterium, *S. aureus*, was associated with the lowest percentage of lactose. The postcalving increase in protein percentage for infected quarters compared with uninfected quarters is contrary to a previous report (Harmon, 1994). Among infected quarters, those with *S. aureus* had the greatest protein percentage. A greater protein percentage in quarters infected with *S. aureus* is probably due to the destructive effect of the bacterial toxins on the mammary epithelium and vascular permeability changes that lead to leakage of some serum protein into milk (Harmon, 1994). At weaning, protein percentage did not differ between infected and uninfected quarters, which is similar to the results described by Harmon (1994). Contrary to our results, *S. aureus*-infected quarters had a lower percentage of protein than uninfected quarters (Watts et al., 1986). In our study, the percentage of SNF was consistently lower for infected than for uninfected quarters, which is comparable to previous results (Nickerson et al., 1995).

Percentages of Infected Cows and Infected Quarters

Oxytetracycline, a bacteriostatic drug used in the present study, has a broad spectrum activity against Gram-positive and -negative bacteria. It is formulated to have a depot release; therefore, after a single intramuscular dose it produces an increase in plasma concentrations, and concentrations in plasma are sustained for 3 to 4 d (Weinstein, 1970). Despite these characteristics, antibiotic treatment at weaning did not reduce ($P > 0.10$) the percentages of infected cows and quarters (CNS, *S. aureus*, and other bacteria) after calving (data not shown) and averaged 43.4 and 13.7%, respectively. Only one study with beef cows evaluated the use of intramammary antibiotics at drying-off on the prevalence of infection at calving (Newman et al., 1991). Infusion of 300 mg of cephapirin was effective in reducing the prevalence of infection in the treated cows (8.2%) compared with untreated cows (22.4%). Cephapirin is effective against staphylococcal and streptococcal intramammary infections; however, it is less effective against Gram-negative bacillus (Watts et al., 1986). Newman et al. (1991) found that staphylococci, streptococci, and *C. bovis* were the organisms present in the cows, and this might explain the high efficiency of the drug.

The combination of treatments administered to cows at weaning and after calving did not influence ($P > 0.10$) the percentage of infected cows and quarters (CNS, *S. aureus*, and "other" bacteria) at the following weaning (data not shown). Treatment did not influence the percentage of quarters infected with different bacterial isolates. Quarters infected with CNS, *S. aureus*, and other bacteria averaged 9.2, 6.8, and 10%, respectively.

It is possible that oxytetracycline might not be effective in the treatment of mastitis in beef cows, or that the intramuscular route of administration of the antibiotic and the frequency used were not appropriate to obtain effective therapeutic action at the mammary gland level. There was no additional benefit of systemic oxytetracycline treatment after intramammary treatment with cephapirin to dairy cows to cure mastitis infections (Erskine et al., 1994). Failure of oxytetracyline treatment at drying-off to influence infections (Soback et al., 1990) was attributed to insufficient serum and tissue drug concentrations, and tetracycline antibacterial activity was diluted out by the milk.

Simultaneous intramammary and intramuscular treatments of cows with antibiotics to reduce mammary infections have been recommended as more effective than the conventional intramammary infusion alone because they act synergistically; the infused antibiotic contacts bacteria in the cisternal area and large ducts, whereas the systemic therapy reaches bacteria that are imbedded deeper in the mammary tissue (Owens et al., 1990; Nickerson et al., 1993).

The percentages of infected cows and infected quarters after calving and at weaning according to parity are given in Table 6. Because of the uneven distribution of cows by parity group, data were unbalanced and chi-square analysis was used to evaluate infection in cows and quarters by parity. After calving, the percentage of infected cows increased ($P < 0.06$) from 19.0 for cows with 2 parities to 47.1 and 46.9 for cows with 3 to 5 and 6 to 10 parities, respectively. The percentage of infected quarters increased ($P < 0.01$) from 4.8 to 16.6 and 19.9 for cows with 2, 3 to 5, and 6 to 10 parities, respectively. Among the infected quarters, cows with two parities had a lower percentage ($P < 0.07$) of infected quarters by CNS than cows with three to five parities. Percentage of quarters infected by *S. aureus* increased ($P < 0.01$) with parity; it was never isolated from quarters of cows with two parities and was more frequently isolated in quarters from cows with three or more parities.

Table 6. Effect of parity on the percentages of infected cows, infected quarters, and nonlactating quarters after calving and at weaning

Item	Parity				
	2	3 to 5	6 to 10	($P <$)[a]	Overall[b]
Postcalving[c], %					
Infected cows	19.0	47.1	46.9	0.06	43.4
Infected quarters	4.8	16.6	19.9	0.01	16.4
CNS[d]	2.4	9.3	5.3	0.07	6.8
S. aureus	0	4.3	8.8	0.01	5.6
Other[e]	2.4	3.0	5.8	NS[g]	4.0
Nonlactating quarters	0	1.0	5.0	—	2.6
Weaning[f], %					
Infected cows	57.1	39.2	61.7	0.05	53.7
Infected quarters	21.4	19.6	36.4	0.01	29.7
CNS[d]	10.7	6.5	8.7	NS	8.1
S. aureus	0	4.6	16.7	0.01	11.5
Other[e]	10.7	8.5	11.0	NS	10.1
Nonlactating quarters	0	1.9	4.8	—	3.3

[a]Chi-square analysis not done for nonlactating quarters.
[b]Represents overall percentages of the herd.
[c]After calving refers to 7 to 14 d postpartum; n = 7, 36, and 67 cows for parity 2, 3 to 5, and 6 to 10, respectively.
[d]CNS: coagulase-negative Staphylococci grouped the following species: *Staphylococcus hycius*, *S. chromogenes*, *S. epidermidis*, *S. cohnii*, *S. warnei*, and *S. hominis*.
[e]Others consisted of *Bacillus* spp., *Corynebacterium bovis*, *Streptococcus* spp. not *Strep. agalactiae*, and undetermined isolates.
[f]Weaning in mid-October at an average age of 212 ± 2 d. Range of Julian birth date was 38 to 177 d; n = 7, 41, and 67 cows for parity 2, 3 to 5, 6 to 10, respectively.
[g]NS = not significant ($P > 0.10$).

Cows with 6 to 10 parities at weaning had the greatest percentage ($P < 0.05$) of infections as well as the greatest percentage ($P < 0.01$) of infected quarters. Percentage of quarters infected by *S. aureus* was greater ($P < 0.01$) for cows with 6 to 10 parities than for cows with 3 to 5 parities. Contrary to what was observed after calving, cows with two parities did not have the lowest percentage of infected quarters, with the exception of percentage of quarters infected with *S. aureus*; cows with three to five parities had the lowest percentage of infected quarters. Cows with 6 to 10 parities had a greater incidence of *S. aureus* infection than cows with 3 to 5 parities. Cows with two parities did not have any infections caused by *S. aureus*. The percentage of infected cows and quarters increased with parity after calving and at weaning. This is in agreement with a study conducted in dairy cows in which the percentage of udder infection was greater for cows that had completed three or more nonlactating periods than for cows with one or two nonlactating periods (Oliver and Mitchell, 1983). *Staphylococcus aureus* is considered a contagious organism, easily spread among dairy cows during milking. In beef cows, the calf may act as a vector in spreading infections from one quarter to another in the same cow and from one cow to another (Day et al., 1987). Cross-suckling of calves probably occurred in the present study because we did not ensure that each dam nursed only its own calf.

The overall percentage of infected cows and infected quarters increased from 43.4 and 16.4, respectively, after calving to 53.7 and 29.7, respectively, at weaning (Table 6). The greatest increase in percentage of infected quarters from calving to weaning was due to *S. aureus* and "other" bacteria at weaning. These results indicate that the incidence of infection in this particular herd increased as lactation progressed. The percentage of infection increases as MSCC increase (Berning and Shook, 1992; Deluyker et al., 1993). In our study, cows of 3 to 10 parities tended to have greater MSCC at calving and also had greater percentages of infected cows and quarters than second-parity cows.

In another study in beef cows during late lactation, the percentage of infected cows was similar to that at weaning in the current study (Newman et al., 1991). In addition, the percentage of infected cows in early lactation was lower than that in the current study after calving. Other studies reported a lower percentage of infected cows than we observed after calving and at weaning (Haggard et al., 1983; Watts et al., 1986).

The prevalence of infected quarters noted in the study by Newman et al. (1991) during early and late lactation is similar to our results. The prevalence of *S. aureus* infection in the study by Newman et al. (1991) was less than in the current study. The percentage of quarters infected with minor pathogens at early and late lactation in the study by Newman et al. (1991) was similar to the percentages for CNS and "other" bacterial isolates in the present study. Other studies with beef cows have found percentages of infected cows at other stages of lactation comparable to those noted in the current study after calving and lower than those reported in the current study at weaning (Kirkbride, 1977; Oliver

and Mitchell, 1983). Percentages of infected quarters and incidence of *S. aureus* infection similar to those seen in the present study have been reported (Watts et al., 1986).

None of the second-parity cows had nonlactating quarters after calving; this increased to 1.0 in cows with 3 to 5 parities and 5.0 in cows with 6 to 10 parities (Table 6). The percentages of nonlactating quarters were similar after calving and at weaning. The overall percentage of nonlactating quarters was 2.6 after calving and 3.3 at weaning.

Implications

Mastitis-causing organisms are prevalent in beef cows. On the average, 43% of the cows and 16% of the quarters in a herd were infected at calving. Furthermore, the incidence of mastitis and the number of blind quarters increased with parity. As the number of infected and nonlactating quarters increased, weaning weight of calves decreased. Treatments or management practices to reduce the incidence of mastitis and the number of nonlactating quarters in beef cows should result in increased calf weaning weight.

Literature Cited

Berning, L. M., and G. E. Shook. 1992. Prediction of mastitis using milk somatic cell count, N-acetyl-β-D-glucosaminidase, and lactose. J. Dairy Sci. 75:1840–1848.

Blackburn, P. S. 1966. The variation in the cell count of cow's milk throughout lactation and from one lactation to the next. J. Dairy Res. 33:193–198.

Day, M. L., K. Imakawa, A. C. Clutter. P. L. Wolfe, D. D. Zalesky, M. K. Nielsen, and J. E. Kinder. 1987. Suckling behavior of calves with dams varying in milk production. J. Anim. Sci. 65:1207–1212.

Deluyker, H. A., J. M. Gay, and L. D. Weaver. 1993. Interrelationships of somatic cell count, mastitis, and milk yield in a low somatic cell count herd. J. Dairy Sci. 76:3445–3452.

Eberhart, R. J. 1986. Management of dry cows to reduce mastitis. J. Dairy Sci. 69:1721–1732.

Eberhart, R. J., and J. M. Buckalew. 1972. Evaluation of a hygiene and dry period therapy program for mastitis control. J. Dairy Sci. 55:1683–1691.

Erskine, R. J., P. C. Bartlett, P. C. Crawshaw, and D. M. Gombas. 1994. Efficacy of intramuscular oxytetracycline as a dry cow treatment for *Staphylococcus aureus* mastitis. J. Dairy Sci. 77:3347–3353.

Haggard, D. L., R. J. Farnsworth, and J. A. Springer. 1983. Subclinical mastitis in beef cows. J. Am. Vet. Med. Assoc. 182:604–606.

Harmon, R. J. 1994. Physiology of mastitis and factors affecting somatic cell counts. J. Dairy Sci. 77:2103–2112.

Houben, E. H. P., A. A. Dijkhuizen, J. A. M. Van Arendonk, and R. B. M. Huirne. 1993. Short- and long-term production losses and repeatability of clinical mastitis in dairy cattle. J. Dairy Sci. 76:2561–2578.

Jeffrey, H. B., R. T. Berg, and R. T. Hardin. 1971. Factors affecting preweaning performance in beef cattle. Can. J. Anim. Sci. 51:561–563.

Kirkbride, C. A. 1977. Mastitis in beef cows. J. Am. Vet. Med. Assoc. 170:1141–1142.

Lucey, S., G. J. Rowlands, and A. M. Russell. 1986. Short-term associations between disease and milk yield in dairy cows. J. Dairy Res. 53:7–15.

Marlowe, T. J., and J. A. Gaines. 1958. The influence of age, sex, and season of birth of calf, and age of dam on preweaning growth rate and type score of beef calves. J. Anim. Sci. 17:706–712.

NMC. 1987. Laboratory and field handbook on bovine mastitis. National Mastitis Council, Arlington, VA.

Natzke, R. P., L. H. Schultz, and T. Kowalczyk. 1966. Effect of antibiotic administration on mastitis screening tests and milk composition. J. Dairy Sci. 49:948–712.

Neville, W. E., Jr. 1962. Influence of dam's milk production and other factors on 120- and 240-day weight of Hereford calves. J. Anim. Sci. 21:315–319.

Newman, M. A., L. L. Wilson, E. H. Cash, R. J. Eberhart, and T. R. Drake. 1991. Mastitis in beef cows and its effects on calf weight gain. J. Anim. Sci. 69:4259–4272.

Nickerson, S. C., W. E. Owens, and R. L. Boddie. 1993. Effects of a *Staphylococcus aureus* bacterin on serum antibody, new infection, and mammary histology in nonlactating dairy cows. J. Dairy Sci. 76:1290–1297.

Nickerson, S. C., W. E. Owens, and R. L. Boddie. 1995. Mastitis in dairy heifers: Initial studies on prevalence and control. J. Dairy Sci. 78:1607–1618.

Oliver, S. P., and B. A. Mitchell. 1983. Susceptibility of bovine mammary gland to infections during the dry period. J. Dairy Sci. 66:1162–1166.

Ostle, B., 1964. Statistics in Research. 2nd ed. The Iowa State University Press, Ames.

Owens, W. E., Z. Y. Xiang, C. H. Ray, and S. C. Nickerson. 1990. Determination of milk and mammary tissue concentrations of ceftiofur after intramammary and intramuscular therapy. J. Dairy Sci. 73:3449–3456.

Paape, M. J., and A. Contreras. 1997. Historical perspective on the evolution of the milk somatic cell count. Flemish Vet. J. 66:93–105.

Pankey, J. W., R. M. Barker, A. Twomey, and G. Duirs. 1982. Comparative efficacy of dry-cow treatment regimens against *Staphylococcus aureus*. N. Z. Vet. J. 30:13–15.

Philpot, W. N. 1969. Role of therapy in mastitis control. J. Dairy Sci. 52:708–713.

Philpot, W. N., and S. C. Nickerson. 1991. A strategy to combat mastitis. In: Mastitis: Counter Attack. p 8. Babson Bros. Co., Naperville, IL.

Sellers H. I., R. L. Willham, and R. C. deBaca. 1970. Effect of certain factors on weaning weight of beef calves. J. Anim. Sci. 31:5–8.

Simpson, R. B., D. P. Wesen, K. L. Anderson, J. D. Armstrong, and R. W. Harvey. 1995. Subclinical mastitis and milk production in primiparous Simmental cows. J. Anim. Sci. 73:1552–1558.

Soback, S., G. Ziv, M. Winkler, and A. Saran. 1990. Systemic dry cows therapy: A preliminary report. J. Dairy Sci. 73:661–666.

Wagner, J. J., K. S. Lusby, J. W. Oltjen, J. Rakestraw, R. P. Wettemann, and L. E. Walters. 1988. Carcass composition in mature Hereford cows: Estimation and effect on daily metabolizable energy requirement during winter. J. Anim. Sci. 66:603–612.

Watts, J. L., J. W. Pankey, W. M. Oliver, S. C. Nickerson, and A. W. Lazarus. 1986. Prevalence and effects of intramammary infection in beef cows. J. Anim. Sci. 62:16–20.

Watts, J. L., S. A. Salmon, R. J. Yancey, Jr., R. S. C. Nickerson, L. J. Weaver, C. Holmberg, J. W. Pankey, and L. K. Fox. 1995. Antimicrobial susceptibility of microorganisms isolated from the mammary glands of dairy heifers. J. Dairy Sci. 78:1637–1648.

Weinstein, L. 1970. Antibiotics. III. The Tetracyclines. In: L. S. Goodman and A. Gilman (ed.) The Pharmacological Basis of Therapeutics. 4th ed. p 1253. The Macmillan Company, New York.

Wilson, L. L., R. J. Eberhart, M. J. Simpson, H. Varela-Alvarez, M. C. Rugh, and L. G. Bair. 1971. Incidence of intramammamary infections and effects of number of lactations, lactation stage, quarter and calf sex on somatic cell content of milk from Angus-Holstein F_1 cows. J. Anim. Sci. 33:433–437.